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(54) Title: TUNED AUTOMATIC BALANCER

(57) Abstract: The present invention provides an automatic tuned balancer for rotating machinery that can be readily implemented with inexpensive machining and easily installed, for example, when a CD-ROM or other disk drive is manufactured. In the preferred embodiment of the invention, a tuned balancer, coaxial with the hub of a rotating shaft, has a balance weight in a ring shape and a spring device that connects the balance weight to the hub. The spring device is fixed to the hub and makes the balance weight rotate with the motor spindle. The balance weight connected to the spring device can move in the radial direction to automatically balance the imbalance mass. The balance weight and spring device are selected so that a desired vibration tuning is achieved that reduces the imbalance over a range of rotation speeds.

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TUNED AUTOMATIC BALANCER

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FIELD OF THE INVENTION

This invention generally relates to an automatic balancer. More specifically, the present invention relates to a balancer for the automatic reduction of imbalances that arise in a rotating body.

BACKGROUND OF THE INVENTION

Imbalance is a dominant cause of vibration in rotating machinery. The phenomenon is characterized by the existence of unequal weight distribution in a rotating body as it spins about a rotating axis. For a rotor with a constant imbalance mass, conventional rotor balancing methods, such as those using commercial balancing machines, can effectively locate the heavy spot, and a balance weight can then be added to the appropriate position 180 degrees opposite the imbalance mass, or the imbalance mass can be removed by drilling. However, for systems having a variable imbalance mass, such that the distribution of mass around the axis of rotation varies during the operation of the machine, or each time the machine is-restarted, such as occurs in CD-drives, DVD-drives, washing machines, hand grinders, etc., these conventional balancing methods cannot be applied.

In general, there are four conventional types of automatic balancers: Leblanc (liquid) balancers, pendulum balancers, ball balancers, and ring balancers. A Leblanc balancer consists of a cylindrical chamber partially filled with a heavy liquid. The related patents are US 4432253, US4517822, US5048367, US5345792, and US5490436.

A pendulum balancer consists of one or more disks mounted on the rotating shaft which carry a number of pendulums. The pendulums are pivoted to the disks. The related patent is US 2405404. Resistance to the pendulums' oscillating motion arises from friction and can cause positioning errors in these balancing pendulums.

An automatic ball balancer is a device using multiple balls guided to move freely in a circular groove housed in the rotor disk and coaxially positioned to the rotating shaft to automatically reduce imbalance that arises from the variable mass distribution in rotating

machinery. There are many patents related this type of balancer, such as US 6061325, US 5845542, US 5829318, US 5816115, US 5460017, US 4075909, US 3854347.

As shown in FIG. 1, the automatic ball balancer has a spindle shaft 1 rotated by a spindle motor 2. A ring shaped groove 31 is provided in the housing 3 joined to the spindle shaft 1. The spindle shaft 1 is supported by the motor board 4 through a bearing 5 such that the spindle shaft 1 is free to rotate relative to the fixed motor board 4. A motor rotor 6 forms the spindle motor 2 and is joined to the spindle shaft 1. The motor rotor 6 has a cylindrical shape and includes a drive magnet 7 joined to the inner surface thereof. The drive magnet 7 is disposed opposite to a stator coil 8 secured to the upper surface of the motor board 4. When an electric current is supplied for operation to the stator coil 8, a magnetic field generated by the stator coil 8 acts on the drive magnet 7. Thus, the drive magnet 7 and the rotor 6 are rotated together with the spindle shaft 1. That is, the spindle shaft 1 serves as a drive shaft for the spindle motor 2. The disk table 9 is joined to the end of the spindle shaft 1. The disk table 9 is a disk-like shape and has an insertion hole formed in the central portion to receive the spindle shaft 1. The leading end of the spindle shaft 1 is press-fit into the insertion hole of the disk table 9 for receiving the spindle shaft 1, and a plurality of balancer balls 10 serving as the balancing members and freely movable in the groove 31 are inserted into the groove.

Due to friction at the contact between the balls and the groove, and the eccentricity of the race over which the balls are moving, the balls can fail to arrive precisely at their desired positions, thereby failing to completely reduce the imbalance.

A ring balancer consists a number of loose rings mounted on the rotating shaft of a machine to reduce any imbalance within the capacity of the device. A patent related to this type is US 5903540.

As shown in FIGS. 2 and 3, the ring balancer has the spindle motor 12 mounted to the deck plate 14 to rotate the turntable 13 coupled to the rotational shaft 11 thereof. The spindle motor 12 includes a motor base 121, the rotational shaft 11, the rotor 123, a stator 127 and bearings 15 and 16. The motor base 121 is coupled to the deck plate 14 and has a through-hole 121a inside. The rotational shaft 11 and the bearings 15 and 16 are assembled in the through-hole 121a. The rotor 123 fixed to one end of the rotational shaft 11 includes a case 124 installed to enclose the stator 127 and a magnet 125 fixed to the inner surface of the case 124. A fixing member 126 is further included between the case 124 and the rotational shaft 11 to prevent the rotational shaft 11 from slipping away from the case 124 or running idly. The stator 127 is fixed to the bottom surface of the motor base 121 and includes a yoke 128 facing the magnet 125 and a coil portion 129 around the yoke 128. The bearings 15 and 16 disposed between the

through-hole 121a and the rotational shaft 11 are provided to support the rotational shaft 11 in the radial and axial directions. A pair of the bearings 15 and 16 is provided inside the through-hole 121a separated by a predetermined distance. That is, the first bearing 15 has an inner race which is fixed to the rotational shaft 11 and an outer race fixed to the through-hole 121a so that movements of the rotational shaft 11 in radial and axial directions can be restricted. The second bearing 16 is inserted into the through-hole 121a to be capable of sliding therein to prevent the rotational shaft 11 from being slanted. A flexible member 17 is disposed between the first and second bearings 15 and 16 inside the through-hole 121a to dampen rotational vibrations of the rotor 123 transferred to the motor base 121. A metal bearing is used as the bearings 15 and 16 considering the positional accuracy necessary for high-speed rotation. Also, it is possible to employ bearings of a different type, i.e., a ball bearing or a dynamic air-pressure bearing. The self-compensating dynamic ring balancer 18 includes at least one pair of rings 181, which are inserted around the rotational shaft 11. Each of the rings 181 is circular, and due to the internal vibrations that arise during the rotation of the rotational shaft 11, the rings 181 rotate around the rotational shaft 11 according to the revolution speed while the revolution of the rotational shaft 11 is restricted. Each of the rings 181 is installed at the rotational shaft 11 between the deck plate 14 and the turntable 13 and has an inner diameter less than that of the turntable 13. Thus, the rings 181 are prevented from escaping from the rotational shaft 11.

Friction between the rings and between them and their support surfaces prevents them from arriving precisely at their desired positions, thereby failing to completely reduce the imbalance.

SUMMARY OF THE INVENTION

The present invention provides an automatic tuned balancer for rotating machinery that can be readily implemented with inexpensive machining and easily installed, for example, when a CD-ROM or other disk drive is manufactured.

In the preferred embodiment of the invention, a tuned balancer, coaxial with the hub of a rotating shaft, has a balance weight in a ring shape and a spring device that connects the balance weight to the hub. The spring device is fixed to the hub and makes the balance weight rotate with the motor spindle. The balance weight connected to the spring device can move in the radial direction to automatically balance the imbalance mass. The balance weight and spring device are selected so that a desired vibration tuning is achieved that reduces the imbalance over a range of rotation speeds. Preferably, the spring device is a wound wire spring in a shape such that its inner

periphery is fixed to the hub and its outer periphery is fixed to the balance weight. The wound wire spring may have various configurations that can firmly secure the balance weight to the hub, and it has less stiffness in the radial direction than in the circumferential and axial directions. In the further preferred embodiment of the invention, the spring device is made of a flexible band.

In the further preferred embodiment of the invention, a damping device is provided to the tuned automatic balancer to dampen transient motions of the tuned automatic balancer. Preferably, the damping device is a housing filled with lubricant and installed at the rotating shaft or the balance weight.

In the further embodiment of the invention, a number of the tuned automatic balancers are installed to the rotating shaft to reduce imbalances in multiple planes in a rotating machine.

In the further preferred embodiment of the invention, a tuned balancer is coaxial with the shoulder of the turntable of a disk-drive device that supports rotating disks, is formed underneath or above the turntable assembly having a balance weight in a ring shape and a spring device that connects the balance weight to the shoulder of the turntable. The spring device is fixed to the shoulder and has the balance weight rotate with the motor spindle. The balance weight connected to the spring device can move in the radial direction to automatically reduce the imbalance. Preferably, the spring device is a wound wire spring or a flexible band in a shape that its inner periphery is fixed to the hub and its outer periphery is fixed to the balance weight. The spring device may have various configurations that can firmly secure the balance weight to the hub and it has less stiffness in the radial direction than in the circumferential and axial directions.

Other objects, features and advantages of the present invention will become apparent from following detailed description when read in conjunction with the drawings and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and is not limited in the figures of the accompanying drawings, in which like references indicate similar elements, and in which:

FIG. 1 is a cross-sectional side view illustrating a conventional disk player with an automatic ball balancer.

FIG. 2 is a cross-sectional side view illustrating a conventional disk player with an automatic ring balancer.

FIG. 3 is a perspective view schematically illustrating a conventional ring balancer; view of the assembly of FIG. 2.

FIG. 4 is a cross-sectional side view of an automatic balancer according to one embodiment of the present invention.

FIG. 5 is a top view of the automatic balancer according to one embodiment of the present invention.

FIG. 6 is a cross-sectional side view of an automatic balancer with a spring device of flexible bands according to one embodiment of the present invention.

FIG. 7 is a cross-sectional side view of the automatic balancer according to a further embodiment of the present invention

FIG. 8 is a cross-sectional side view of the automatic balancer for a disk-drive device according to a further embodiment of the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

An automatic balancer to automatically reduce imbalance in rotating machinery such as computer disks, CD-ROMs, digital video disks, hand-held tools, ceiling fans, etc, is disclosed. An automatic balancer according to the invention is illustrated generally in FIGS. 4 and 5. It is comprised of a balance weight 20 and a spring device 22. The operation of an imbalanced body is generally illustrated at 23, which generates an out of balance condition. The automatic balancer is placed near the imbalanced body. The balance weight 20 has an annular structure, defined by sides 201 and 202 that can be provided by stamping the balance weight 20 from sheet metal such as type 301 stainless steel, or by other forming methods. Further, as shown, the balance weight 20 has an inner periphery 203 and an outer periphery 204, centered on an axis that extends perpendicularly to the sides 201 and 202 and will generally coincide with the axis of rotation of the rotating shaft 21. The inner periphery 203 of the balance weight 20 is formed on a diameter that is larger than the hub 24 affixed to the rotating shaft 21 so that a spring device 22 can connect the inner periphery 203 of the balance weight 20 to the hub 24 of the rotating shaft 21. The balance weight 20 will rotate with the rotating shaft 21 but is free to move in the radial direction. Moreover, as is particularly shown in FIG. 4, a groove 205 is formed on the surface of the inner periphery 203. Preferably, the spring device 22 is a wound wire spring 221 in a shape so that its inner periphery 222 is fixed to the hub 24 and its outer periphery 223 is fixed to the balance weight 20. The wound wire spring 221 may have various configurations that can firmly secure the balance weight 20 to the hub 24 of the rotating shaft 21 and has less stiffness in the

radial direction than in the circumferential and axial directions. In order to secure the balance weight 20 to the rotating shaft 21, the wound wire spring 221 is formed to have a shape of its outer periphery 223 such that it can be engaged with the groove 205 of the balance weight 20. Similarly, the wound wire spring 221 is formed to have a shape of its inner periphery 222 such that it can be engaged with the groove 241 of the hub 24. The inner periphery 222 of the wound wire spring 221 is formed on a diameter that is slightly smaller than that of the groove 241 on the hub 24 of the rotating shaft 21 so that the inner periphery 222 of the wound wire spring 221 will mate with the hub 24 firmly causing the wound wire spring 221 to grip the hub 24.Similarly, the outer periphery 223 of the wound wire spring 221 is formed on a diameter that is slightly larger than that of the groove 205 on the inner periphery 203 of the balance weight 20 so that the outer periphery 223 of the wound wire spring 221 will firmly mate with the balance weight 20 and thus cause the wound wire spring 221 to grip the balance weight 20. Other joining approaches, such as welding, riveting, or fasteners may be used to connect the balance weight 20 and the hub 24 to the spring device 22. In such a case, the grooves 205 and 241 on the balance weight 20 and the hub 24 can be omitted. As noted above, an aspect of the present invention is that the configuration of the wound wire spring 221 can be selected to exhibit a range of different shapes to permit the desired stiffnesses in the radial, circumferential and axial directions.

In the further preferred embodiment of the invention, the spring device 22 is a flexible band 224 as shown in FIG 6. The band is made of steel, plastic, or similar flexible material. The configuration of the flexible band 224 can be selected to exhibit a range of different shapes to permit the desired stiffnesses in the radial, circumferential and axial directions.

The mass of the balance weight 20 and the radial stiffness of the spring device 22 are selected such that the balance system is tuned to reduce the imbalance over a range of rotation speeds.

In a further preferred embodiment of the invention, as shown in FIG. 7, a damping device 25 is provided to the automatic balancer to dampen transient vibrations of the automatic balancer. Preferably, the damping device 25 is a housing 26 filled with lubricant 27 and installed on the rotating shaft 21 to enclose the balance weight 20. The housing comprises a cover 28 coupled with an open portion of the housing 26. In order to avoid friction occurring between the balance weight 20 and the housing 26, the balance weight 20 does not make contact with the housing 26. The lubricant 27 in the housing 26 provides the damping to the balance weight 20 during operation.

In a further embodiment of the invention, a damping fluid can be contained in cavities in the balance weight 20.

In a further embodiment of the invention, a number of the tuned automatic balancers are installed to the rotating shaft to reduce imbalances occurring in multiple planes of a rotating machine.

A further embodiment of the invention as it applies to disk-drive devices is illustrated in FIG 8, which shows a cross-sectional side view of a tuned automatic balancer 30 for use in a disk-drive device in which a spindle shaft 31 is rotated by a spindle motor 32. A turntable 39 is joined concentrically to the spindle shaft 31. The spindle shaft 31 is supported by the motor board 34 through a bearing 35 such that the spindle shaft 31 is free to rotate relative to the fixed motor board 34. A motor rotor 36 forming the spindle motor 32 is joined to the spindle shaft 31. The motor rotor 36 has a cylindrical shape and includes a drive magnet 37 joined to the inner surface thereof. The drive magnet 37 is disposed opposite to a stator coil 38 secured to the upper surface of the motor board 34. When an electric current for operation is supplied to the stator coil 38, a magnetic field generated by the stator coil 38 acts on the drive magnet 37. Thus, the drive magnet 37 and the motor rotor 36 are rotated together with the spindle shaft 31. Thus, the spindle shaft 31 serves as a drive shaft for the spindle motor 32. The turntable 39 is joined to the leading end of the spindle shaft 31. The turntable 39 is a disc-like shape in one end and has an insertion hole formed in the central portion thereof to receive the spindle shaft 31. The spindle shaft 31 is press-fit into the insertion hole of the turntable 39 for receiving the spindle shaft 31, or fixed in some other manner, so that the turntable 39 rotates with the spindle shaft 31. A feature of turntable 39 that is found on the other end of the turntable 39 is, specifically, a circular shoulder 33 that is formed and disposed in a coaxial relation with the spindle shaft 31. An enhancement of the invention with respect to the shoulder 33 that will be discussed below is that the shoulder 33 is undercut to form a groove 331. In the practice of the present invention, the automatic balancer 30 is comprised of the balance weight 40 and a spring device 41. The balance weight 40 has an annular structure, defined by sides 401 and 402 that can be provided by stamping the balance weight 40 from sheet metal, such as type 301 stainless steel or other material, or by other forming methods. Further, as shown, the balance weight 40 has a circular inner periphery 403 and a circular outer periphery 404, centered on an axis that extends perpendicularly to the sides 401 and 402 and will coincide with the axis of rotation 311 of the spindle shaft 31 when the disk-drive device is assembled. The inner periphery 403 of the balance weight 40 is formed on a diameter that is larger than the shoulder 33 on the turntable 39 so that a spring device 41 can connect the inner

periphery 403 of the balance weight 40 to the shoulder 33 of the turntable 39 such that it causes the balance weight 40 to rotate with the spindle shaft 31, while it is free to move in the radial direction. The spring device 41 is a wound wire spring or flexible band in a shape that has its inner periphery fixed to the shoulder 33 and its outer periphery fixed to the balance weight 40. The spring device 41 may have various configurations that can firmly secure the balance weight 40 to the shoulder 33 of the turntable 39 and has less stiffness in the radial direction than in the circumferential and axial directions. In order to secure the balance weight 40 to the turntable 39, the spring device 41 is formed to have a shape of its outer periphery such that it can be in engaged with the groove 405 of the balance weight 40. Similarly, the spring device 41 is formed to have a shape of its inner periphery such that it can be in engaged with the groove 331 on the shoulder 33 of the turntable 39. The inner periphery of the spring device 41 is formed on a diameter that is slightly smaller than that of the groove 331 on the shoulder 33 of the turntable 39 so that the inner periphery of the spring device 41 will mate with the shoulder 33 firmly, causing the spring device 41 to grip the shoulder 33. Similarly, the outer periphery of the spring device 41 is formed on a diameter that is slightly larger than that of the groove 405 on the inner periphery 403 of the balance weight 40 so that the outer periphery of the spring device 41 will mate with the balance weight 40 firmly, causing the spring device 41 to grip the balance weight 40. Other joining techniques such as welding, riveting, or fasteners may be used to connect the balance weight 40 to the turntable 39. In such a case, the grooves 405 and 331 on the balance weight 40 and the turntable 39 can be omitted.

In the present invention, it is a characteristic feature that a tuned automatic balancer is provided to reduce rotating imbalance. The balance weight of the automatic balancer can rotate with the rotating shaft and move in the radial direction to the desired position at a point 180 degrees opposite the position of the imbalance mass. The distance of the movement of the balance weight varies proportionally to the mass of the imbalance and its distance from the rotational center. Since contact friction is nonexistent in the present invention, the balance weight can move precisely to the desired position and effectively reduce the imbalance and successfully reduce the vibration caused by the imbalance mass.

Since the mass of the balance weight and the radial stiffness of the spring introduce additional dynamics to the rotating system, they are selected such that the balance system is tuned to reduce the imbalance over a range of rotation speeds.

It should be understood that the invention is not limited to the particular embodiments shown and described herein, but that various changes may be made

without departing from the spirit or scope of this concept as defined by the following claims.

What is claimed is:

1. An automatic balancer for a rotating body comprising:
   at least one balance weight having an inner periphery and an outer periphery;
   an annular support means coaxially and firmly mounted to the rotating shaft and in rotation with the rotating shaft;
   a spring means for connecting the balance weight to the supporting means so that the balance weight rotates with the rotating shaft and is movable in the radial direction,
   the balance weight and spring means are tuned so as to reduce the imbalance over a range of rotation speeds.
2. An automatic balancer according to claim 1, wherein said annular support means comprises a hub joined concentric to the rotational shaft.
3. An automatic balancer according to claim 1, wherein said spring means comprises a wound wire spring in a shape such that its inner periphery is fixed to said hub and its outer periphery is fixed to said balance weight; said wound wire spring may have various configurations that can firmly secure said balance weight to said hub and has less stiffness in the radial direction than in the circumferential and axial directions.
4. An automatic balancer according to claim 1, wherein said balance weight comprises an annular groove on its inner periphery.
5. An automatic balancer according to claim 1, wherein said hub comprises an annular groove on its outer periphery.
6. An automatic balancer according to claim 3, wherein said wound wire spring is fixed to said groove of said hub and said groove of said balance weight by a snug fitting.
7. An automatic balancer according to claim 3, wherein said wound wire spring is fixed to said balance weight and said hub by welding, riveting , or fasteners.
8. An automatic balancer according to claim 1, wherein said spring means comprises flexible bands in a shape that its inner periphery is fixed to said hub and its outer periphery is fixed to said balance weight; said flexible band may have various configurations that can firmly secure said balance weight to said hub and has less stiffness in the radial direction than in the circumferential and axial directions.
9. An automatic balancer according to claim 8, wherein said flexible bands are fixed to said hub and said balance weight by a snug fitting.

10. An automatic balancer according to claim 8, wherein said flexible bands are fixed to said balance weight and said hub by welding, riveting, or fasteners.
11. An automatic balancer according to claim 8, wherein said bands are made of steel, plastic, or other flexible material.
12. An automatic balancer according to claim 1, including a damping device provided to dampen transient vibrations of the tuned automatic balancer; said damping device is a housing filled with lubricant and attached to the rotating shaft, or is one or more cavities in the balance weight filled or partially filled with a liquid.

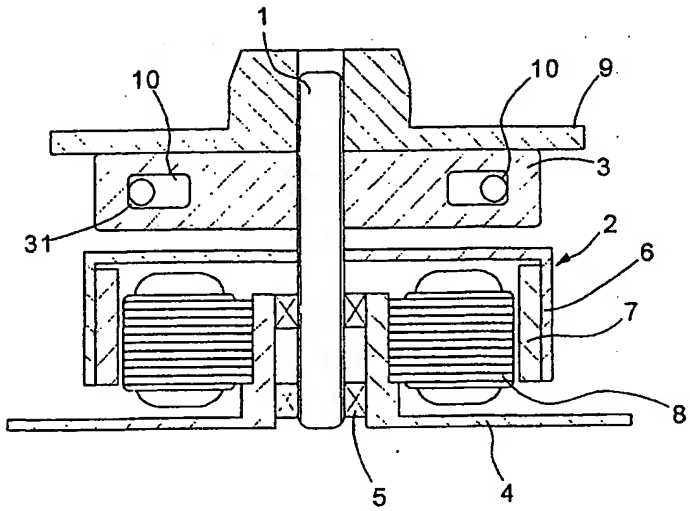
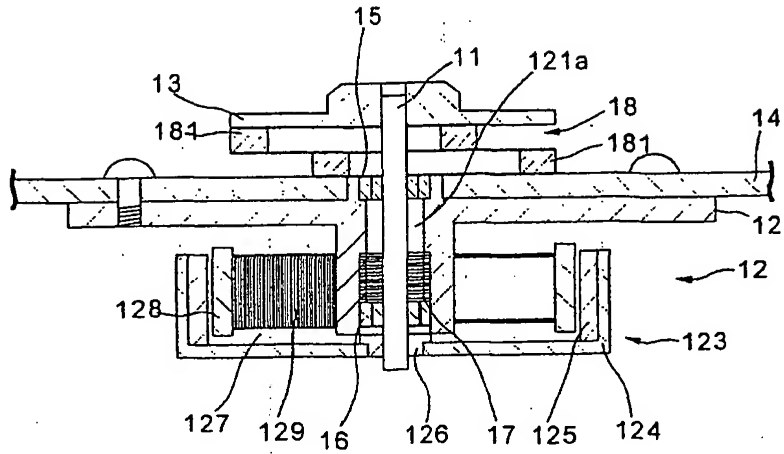


FIG. 1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121a
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14
181
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125
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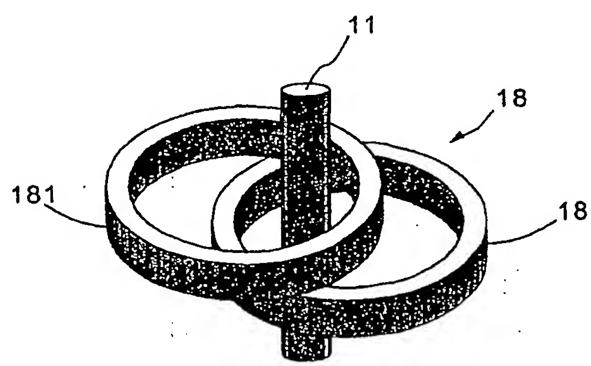
FIG. 2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181
18

FIG. 3

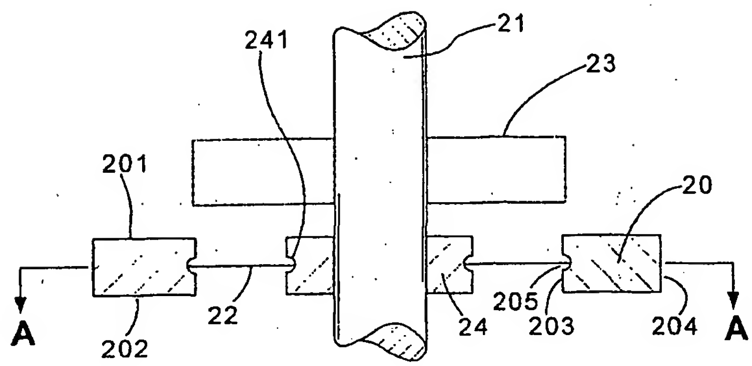

FIG. 4

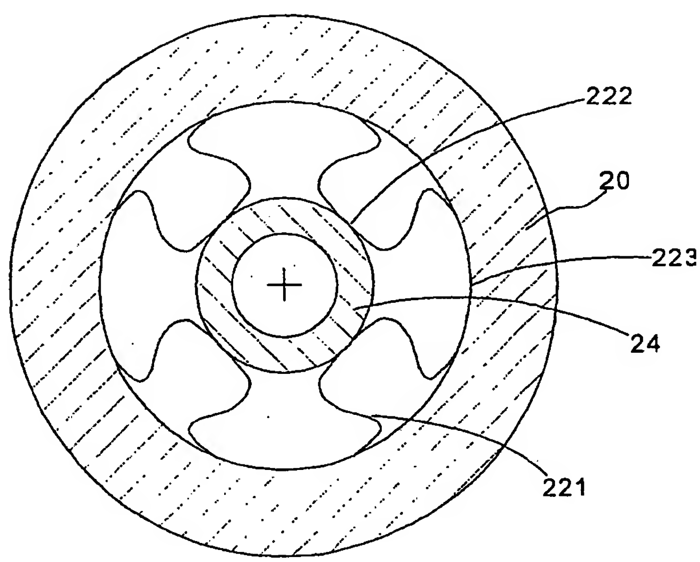

FIG. 5

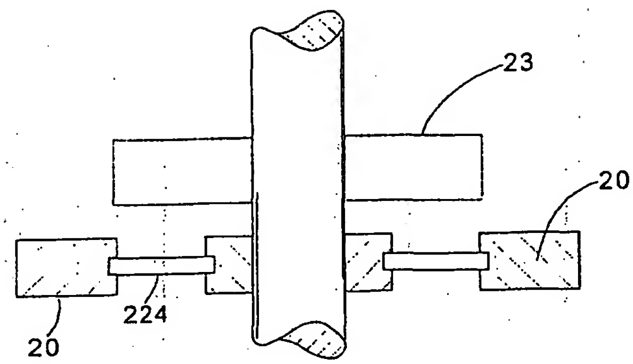

FIG. 6A

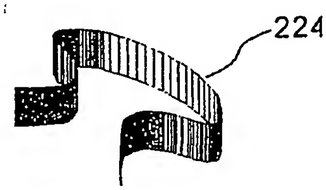

FIG. 6B

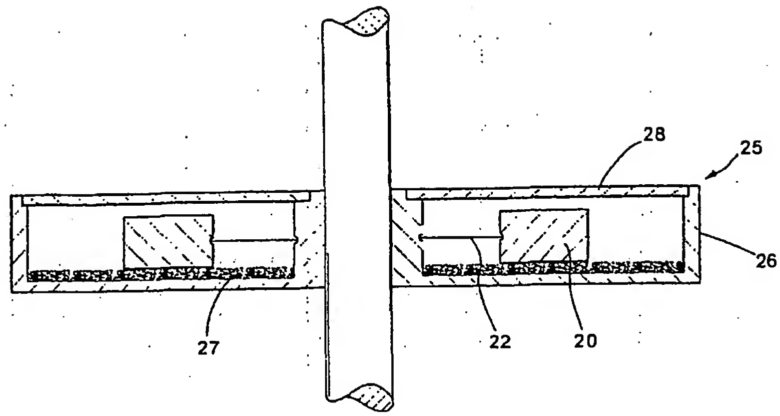
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FIG. 7

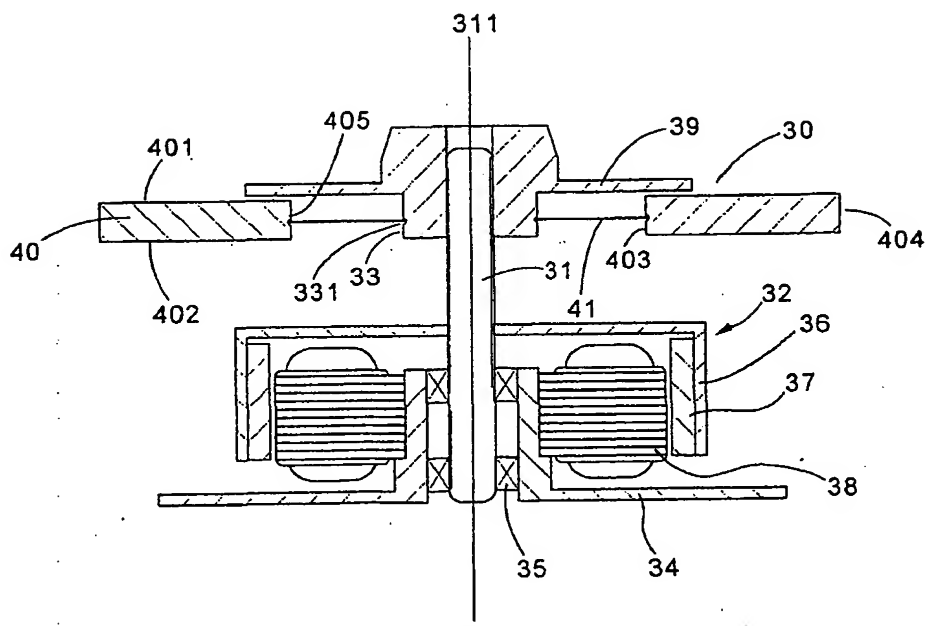
311
405
401
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FIG. 8

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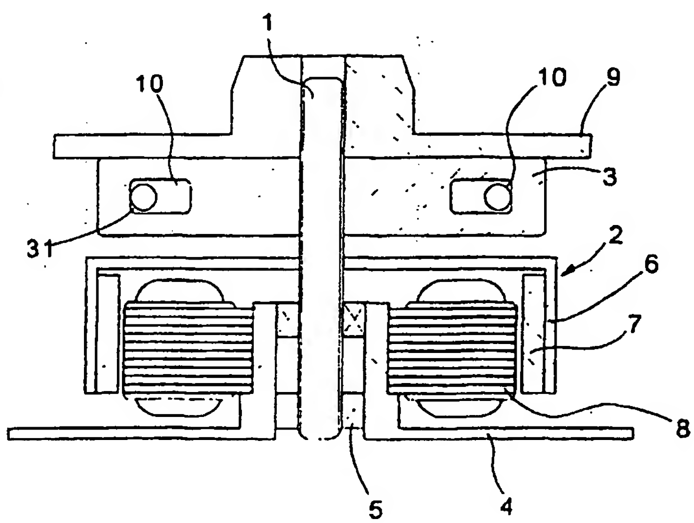

(57) Abstract: The present invention provides an automatic tuned balancer for rotating machinery that can be readily implemented with inexpensive machining and easily installed, for example, when a CD-ROM or other disk drive is manufactured. In the preferred embodiment of the invention, a tuned balancer, coaxial with the hub of a rotating shaft, has a balance weight in a ring shape and a spring device that connects the balance weight to the hub. The spring device is fixed to the hub and makes the balance weight rotate with the motor spindle. The balance weight connected to the spring device can move in the radial direction to automatically balance the imbalance mass. The balance weight and spring device are selected so that a desired vibration tuning is achieved that reduces the imbalance over a range of rotation speeds.

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INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16F15/12 F16F15/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 283 234 A (CUBIC ENG KK) 21 September 1988 (1988-09-21) column 5, line 9 - line 40 figure 2	1,2,4,5
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 February 2002	26/02/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Beaumont, A

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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